Loop aerials close to ground

by L. V. MAYHEAD, G3AQC*

THE cubical quad aerial has been used by amateurs on the higher frequency bands since the second world war with great success. It exhibits lower angle radiation at the same height compared with a dipole, and has other advantages including greater bandwidth. The quad is a form of loop aerial and can be used without a resonant reflector as a bi-directional radiator with a gain slightly in excess of a dipole.

Loop aerials, sometimes known as magnetic dipoles, have been used for many years—a frame aerial is in fact a multi-turn loop. The shape of the loop is not of great importance although its efficiency is proportional to its area. Both the square (quad) and triangular delta shapes have maximum areas when the sides are of equal length. In practical situations it is possible to modify this requirement but the efficiency will decrease and the aerial will become more frequency conscious. The delta loop aerial, like the quad, exhibits bi-directional properties and if erected at a great reasonable, locating the centre of a 3·8MHz quad $\frac{1}{4}\lambda$ above ground would mean that the top would be at a height of 90 to 100ft, clearly impossible for most people.

In an attempt to lower the angle of radiation still further, W6DL suggested the delta configuration. His triangle was equi-sided and had the base above the apex. This configuration tends to raise the effective height of the aerial since the centre of area of a triangle is higher than that of a square. In June 1971 G6LX reported his findings using a number of loop configurations including quad, oblong and triangle shapes [2], all of which produced good dx results on 80m at the G6LX location.

A stretched quad (oblong) aerial which the author erected for use during the winter of 1971 was changed to the inverted loop configuration with the base uppermost, and improved results were obtained. However, it was felt that in comparison with other stations better performance ought to be possible.

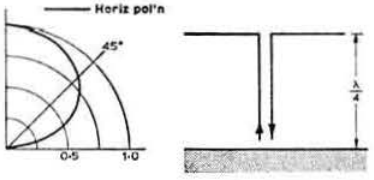

Fig 1. Horizontal dipole at $\frac{1}{4}\lambda$

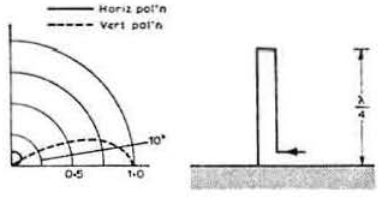

Fig 2. Vertical folded $\frac{1}{4}\lambda$ high

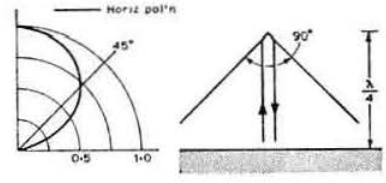

Fig 3. Inverted-V at $\frac{1}{4}\lambda$

enough height will show well-defined minima in the direction of the wire. The Bellini-Tosi direction-finding system makes use of this property of the loop aerial.

On the higher frequency amateur bands, 14, 21 and 28MHz, the height of an aerial is very rarely less than $\frac{1}{2}\lambda$. At this height a loop can be fed at any point and the feed point becomes a current maximum. If a quad is fed at the centre of one vertical side the resulting radiation is vertically polarized, if fed at the centre of a horizontal side the radiation is horizontally polarized.

If the aerial could be suspended in free space, radiation perpendicular to the plane of the aerial would have a circular distribution. However, when erected close to the ground the radiation pattern is modified and the field at a distant point is made up of both direct radiation and radiation reflected from the ground. W. I. Orr states in his book about quad aerials [1] that at a height of $\frac{1}{4}\lambda$ the main lobe is at an angle of 26° to the horizontal, compared with 30° for a dipole at the same height. However, as the aerial approaches closer to the ground the angle of radiation becomes lower than that of a dipole, so that at $\frac{1}{4}\lambda$ the main lobe is at 40° compared with 90° for a dipole. Thus the quad is a most satisfactory aerial when used at these heights. However, if the effective height is measured from the centre of area of the loop, as seems

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The aerial appeared to put out an extremely good signal up to 1,000 miles but beyond this range performance fell off. The feed point was shifted to one corner and the strength of local signals fell very considerably. Discussions on the air with other amateurs led the author to believe that little was known about the radiation pattern of loop aerials with respect to the feed point and closeness to ground.

It was therefore decided to carry out tests on model aerials at 470MHz, since this resulted in a wavelength of approximately 24in and equipment was available in the form of a tv field-strength meter. At this frequency a reasonable ground plane could be established using a 6ft by 4ft sheet of aluminium. Both triangle and quad aerials were constructed and these were compared with dipole and vertical aerials.

Test results

The aerials were erected at scale height above a perfect ground consisting of an aluminium sheet approximately 3λ by 2λ. While it is admitted that the use of such a good ground system is not representative of actual conditions, it does make a good starting point to eliminate the effect of poor ground conductivity and to investigate radiation angles in both vertical and horizontal (azimuth) planes.

The aerials were fed from an oscillator located below the ground plane with the shortest possible feed line to eliminate radiation from the feeder, which would not be matched and

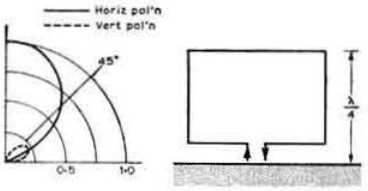

Fig 4. Quad at ½λ, base feed

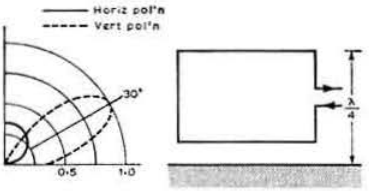

Fig 5. Quad at ½λ, side feed

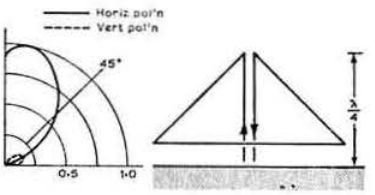

Fig 6. Delta loop at ½λ, apex feed

which would probably have quite a high swr. No attempt was made to match the aerials to the oscillator since the purpose of the experiment was not to determine radiation efficiency as such but to investigate radiation patterns. The receiving aerial was a simple ½λ dipole which could be rotated so as to respond to either vertically or horizontally polarized radiation.

Tests were carried out for radiation in the vertical plane, with the receiving aerial located approximately 5λ from the transmitting aerial and at the point of maximum radiation in the horizontal plane. Checks were carried out for both horizontal and vertical polarization, and diagrams showing the relative signal strength for various vertical angles were drawn.

Fig 1 shows a horizontal dipole with its top at ¼λ. The angle of the lobe corresponds with that given in the ARRL *Antenna Book* [3] for a dipole at ¼λ. Note that the radiation was entirely horizontally polarized. The second aerial configuration checked was a vertical, folded to increase its impedance, and this was made ¼λ high since it is the maximum height at which amateurs are likely to be able to erect an 80m aerial. This is shown in Fig 2 and it will be seen that there is a very low angle vertically-polarized lobe and a very small horizontal lobe, which was probably due to the folded construction since the separation between the elements was relatively large compared to the wavelength.

The next aerial checked was the inverted-V configuration (Fig 3), and this is of interest since it indicates that no advantage is obtained over a flat-topped ½λ dipole, except of course that it is much easier to erect, needing only one support. Up to the point where the efficiency falls off (90°) the angle between the legs is not important and appears only to affect the drive impedance. In Fig 4 the radiation obtained from a quad is shown. Note that the feed point is at the centre of the horizontal base. This aerial appears to produce mainly horizontally polarized radiation with a very small vertical lobe. Note also the relatively high angle which is consistent with horizontal aerials close to ground. Fig 5 shows the improvement obtained by feeding in a vertical side. There is a good vertically polarized lobe at 30°, and a quite good horizontal lobe which might cause trouble on reception from local signals putting in a high-angle signal.

Having established a degree of confidence in respect of known aerial configurations, the loops were next investigated. In Fig 6 is shown a delta loop fed at the apex—this aerial is basically a modified inverted-V, the idea being that it might be possible to switch from the V to loop configuration and thus alter the aerial radiation pattern. However, as the figure shows, the radiation is again high angle and horizontally polarized. In Fig 7 a most interesting configuration is shown: the expected horizontal lobe appears, but in addition a large vertical lobe at quite a low angle. This configuration was checked at harmonic frequencies and forms the basis of a useful multiband dx aerial which will be described later.

To continue with the delta configuration, in Fig 8 the feed was shifted to base but the results were rather disappointing. However, when the feed was shifted to a corner the radiation angles which had been suspected from the full scale aerial were immediately apparent; Fig 9 illustrates the very low vertical lobe and a smaller horizontally polarized lobe. During discussions on the air, G3TZH reported obtaining very good results from a loop aerial feed at one corner as shown in Fig 10—this configuration exhibits very similar radiation angles to that of Fig 9 and has the advantage that only one support is required. The slightly higher radiation angle of the vertical lobe is probably due to the greater effective height of the Fig 9 configuration.

Full scale tests were carried out with the Fig 9 configuration, with arrangements to switch to the Fig 7 configurations, and a drop of 15 to 20dB was obtained on local signals. Note that by "local" is meant signals beyond ground wave range which were being received from the ionosphere, ie 100 miles in daylight.

Further checks have shown that the corner-fed aerial has similar radiation properties to the vertically polarized voltage fed element described by W8JK and reported by G3VA in *TT* [4]. It closely resembles a pair of phased verticals at ½λ spacing and has the great advantage that it is much easier to feed and does not require a low resistance local ground in order to obtain maximum radiation efficiency. However, in order to exploit the aerial's low angle properties a good ground extending several wavelengths around it is required, which is true of any aerial relying on the interference of the direct and reflected rays. (With the exception of the Beverage receiving aerial, of course).

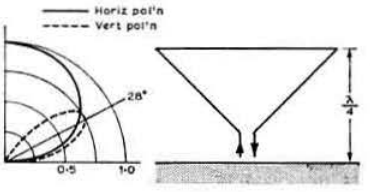

Fig 7. Inverted delta loop at ½λ, apex down feed.

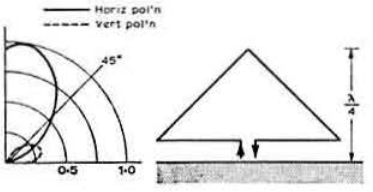

Fig 8. Delta loop at ½λ, base feed

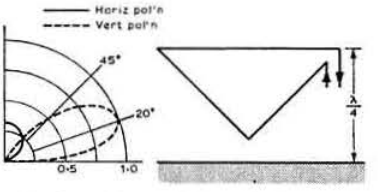

Fig 9. Inverted delta loop at ½λ, corner-up feed

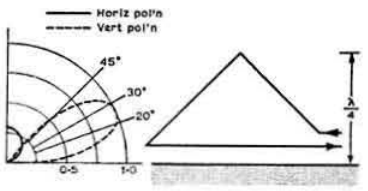

Fig 10. Delta loop at ½λ, corner-down feed

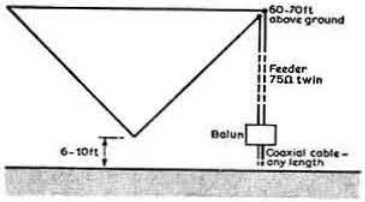

Fig 15. Delta loop of Fig 9 (similar dimensions for Fig 10 configuration, base 10ft, height 12ft). Dimensions for 3·8MHz, 1λ approximately 270ft. Single band. Radiation resistance 60Ω.

Bandwidth			
Freq	SWR	Freq	SWR
3·750	1·40:1	3·825	1·20:1
3·775	1·20:1	3·850	1·40:1
3·800	1·15:1		

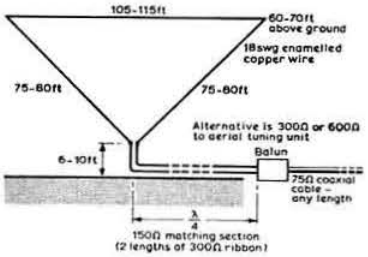

Fig 16. Inverted delta loop of Fig 7. Dimensions for 3·8MHz, 1λ approximately 270ft. Can be used on other bands. Radiation resistance 180Ω.

Multiband		Bandwidth	
Freq	SWR	Freq	SWR
3·800	1·10:1	3·750	1·20:1
7·100	1·00:1	3·775	1·15:1
7·000	1·05:1	3·800	1·10:1
14·100	1·15:1	3·825	1·15:1
14·350	1·45:1	3·850	1·25:1
21·100	2·00:1		
21·450	2·50:1		

Results

Two aerials have been constructed as a result of this work. The first is a single-band low-angle aerial of the Fig 9 configuration, and details are given in Fig 15. Note that the radiation resistance is approximatey 60Ω and thus a reasonable match can be obtained using either 50Ω or 75Ω cable. In the author's case the section between the aerial and balun was made approximately ¼λ and the length adjusted to produce the best swr. This aerial can be erected on a single support as in Fig 10; the effective height is slightly lower, but the dimensions will be similar. Coaxial 50Ω or 75Ω feeder can be used and the outer sheath should be connected to the lower horizontal wire, which should be at a minimum height of 10 to 12ft. The wire used does not have to be very heavy gauge—18swg is quite light and produces a reasonable bandwidth.

The second aerial used by the author is the Fig 7 configuration, described in Fig 16. This has a useful low angle lobe as well as a good horizontally polarized lobe and makes a good general purpose aerial which can also be used on other bands where it will exhibit multi-lobe radiation. The radiation resistance is approximately 180Ω and the aerial can be fed by 300Ω ribbon or 600Ω open line via a simple atu. Alternatively the author has used a ¼λ matching section, consisting of two parallel lengths of 300Ω ribbon.

In order that the radiation patterns shown may be obtained in practice, it is necessary to use a balun between the feeder and the unbalanced output of the transmitter/receiver. The aerials of Figs 9 and 10 are unbalanced with respect to ground and should be fed via a balance to unbalance transformer in order to avoid cross polarization.

During the model experiments quite large horizontal lobes were obtained from these aerials before this effect was discovered and eliminated by means of a coaxial balun. The configuration of Fig 7 is balanced with respect to ground and this balance should be maintained in order that the vertical radiation pattern should not be disturbed (Marconi effect). Several amateurs have obtained good results with the Fig 9 aerial by feeding directly with 50 or 75Ω coaxial, in which case the disturbance is minimized by connecting the outer screen of the coaxial to the horizontal wire of the loop.

Both these loop aerials can be adjusted for optimum performance on a particular frequency as follows. Start with approximately 275ft of wire (for an 80m loop) and erect this in the desired configuration. Feed the aerial with a short length of feeder or a feeder which is a multiple of ½λ and plot the swr across the band (the lowest swr will indicate the resonant frequency) and shorten the aerial until the lowest swr is obtained at the desired operating frequency. It is then only necessary to adjust the matching section to obtain the lowest swr, at this frequency, and the aerial is optimized. Both aerials were adjusted to resonance and very low swr by means of the ¼λ sections described—in the case of the corner fed aerials of Figs 9 and 10 the radiation resistance is so close to either 50Ω or 75Ω that it may not be considered necessary to match more accurately. However, by using a ¼λ length of 75Ω feeder an almost perfect match can be obtained. The feeder is made rather long and then shortened until the lowest swr is obtained. This technique can also be used on any aerial.

Conclusion

To complete the work on radiation patterns some of the aerials were checked in the horizontal plane, since the familiar figure-of-8 pattern for a dipole is only obtained when an aerial is erected in free space. Figs 11 to 14 show azimuth patterns obtained: note that a ½λ dipole at ¼λ height had a 6 to 8dB front-to-side ratio—when the height was increased to 0·3λ this increased to approx 20dB. The two delta loop configurations produced similar results—the horizontal component producing a side/front ratio of 5 to 6dB, while the vertical mode produced a ratio of only 2 to 4dB. This is similar to the ratio for the Fig 9 loop configuration shown in Fig 14. Fig 13 shows definite multi-lobe properties for the inverted delta loop of Fig 7, when the length is 2λ, ie an 80m loop operated on 40m. More lobes would no doubt appear on 14 and 21MHz.

Further work remains to be done on these azimuth patterns, particularly in relation to the vertical angle at which the pattern is taken. This must wait, however, until more time is available.

The predominantly vertically polarized configurations of Figs 9 and 10 may not produce the expected large increase in signal strength in some situations. This may be due to (*a*) poor soil conductivity preventing the re-inforcement of the low angle signal, and/or (*b*) local obstructions such as trees, houses etc which attenuate the low angle radiation directed at them. At the G3AQC location the author is able to switch

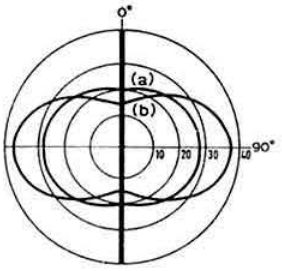

Fig 11. Dipole at (a) 0·25λ (b) 0·30λ. Horizontal radiation at 30°. Direction of aerial wire 0-180°

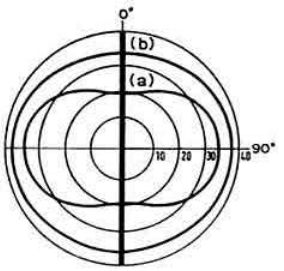

Fig 12. Inverted delta loop of Fig 7. Top at 0·25λ. (a) Horizontal at 30°. (b) Vertical at 15°. Direction of aerial wire 0—180°

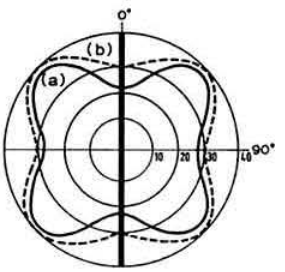

Fig 13. Inverted delta loop of Fig 7. Length = 2λ. Height = ½λ. (a) Elevation 30°, horizontal polarization. (b) Elevation 15°, vertical polarization. Direction of aerial wire 0—180°

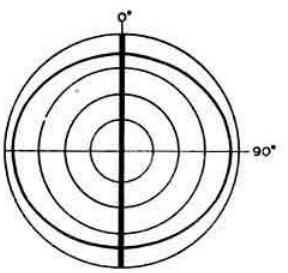

Fig 14. Delta loop of Fig 9. Top at 0·25λ. Elevation 15°. Vertical polarization. Direction of aerial wire 0—180°

between three aerials, a G5RV used as a control aerial, an inverted loop as Fig 7 and a Fig 9 loop fed in the manner described in [4]. Considerable checking to date on paths to Canada, the USA and long path to New Zealand on 80m indicates that the Fig 7 loop is 5 to 10dB up on the G5RV, but that there is no further advantage from the Fig 9 aerial. However, the G3AQC location is quite poor; the soil is sand/gravel and 80ft trees are within a few feet of the aerial. When erected by G3TZH in an ideal situation—a very flat area with gravel pits and a water table only 18in deep — quite remarkable results were obtained for the Fig 10 configuration. Belgian amateur ON4UN also reports a gain of 5dB from this aerial.

It is hoped that the measurements made will help to clear up some of the doubts about loop configuration and that the designs described will enable many amateurs to enjoy improved performance, particularly in relation to dx working on the lower frequency bands. The author would be pleased to hear from any amateur who has any of the loop configurations described.

References

[1] *Quad antennas*, W. I. Orr Radio Publications, USA.
[2] "Odd shaped antennae", R. L. Glaisher, G6LX. *SWM* June 1971.
[3] *Antenna Handbook*, ARRL.
[4] "Technical Topics", Pat Hawker, G3VA. *Radio Communication* April 1973.

The Comdel CSP-11 speech processor — Continued from page 297

The input impedance is high, suiting many popular microphones, and the output requires a medium to high impedance load. Front panel controls consist of an on-off switch, a processor in-out switch and a gain control. The latter adjusts the level subsequently fed to the clipping stage, the point at which clipping commences being fixed. As the control is advanced beyond this threshold the degree of clipping will be increased.

Measurements made by the reviewer suggest that about 15dB of clipping is an optimum setting. Without test gear an operator should seek on-the-air reports for various settings, adjusting for increased "punch" without an excessively clipped-sounding speech quality.

The in-out switch allows comparison to be made between processed and unprocessed speech, and here the reviewer has one criticism. When switched "out" the CSP-11 has approximately unity gain, whereas in the "in" position the unit has about 10dB overall gain. This can falsify comparisons in favour of the latter position unless a compensating adjustment is made to the transceiver's microphone gain control. Unity gain at clipping threshold would have been preferable.

Six internal HP2 cells render the unit entirely self-powered, and should last for several hundred hours. Alternatively, an external supply may be taken from the transceiver. Dependant on the voltage available, a suitable dropping resistor may have to be fitted; with a 9V supply only 18mA is required.

The CSP-11 on the air

The processor was used daily over a period of two weeks at the Redifon Amateur Radio Club station, G4BFW, in Crawley, Sussex. At the time the club's 400W linear was off the air and a 100W solid-state amplifier was in use. The aerial was a TH6DXX on a 60ft Versatower.

Reports from stations worked varied from "no difference between in and out" to "an improvement of two S-points". Surprisingly an improvement in speech quality was frequently remarked upon.

In theory an S-meter should not show an increased peak reading when receiving a clipped signal, but a higher average deflection will occur. Certainly the collector-current meter on the pa spent a greater time nearer maximum with the clipper in circuit.

In the opinion of the reviewer and other operators at G4BFW, the CSP-11 more than made up for the 6dB difference between the 100W and 400W amplifiers. With reports of 5 and 9 from VK, ZL and the Pacific there seemed little necessity to exceed 100W p.e.p.

For the expenditure of less than half the cost of a linear, owners of 100W transceivers can achieve a similar improvement in talk-power. Some tv deflector-valve PAs may not take kindly to the higher average power, but those with blowers should survive.

The reviewer is indebted to Interface International for the loan of the CSP-11, he was sorry to have to return it.